THE BASIC CONCEPT OF GROUND ANCHOR REPAIR AND TYPES

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ABSTRACT

In order to maintain the performance of existing anchors it is important that the replenishment of underhead protection (below the bearing plate) should be considered. In this paper, the basic concept of anchor repair and an example of repair work are given.

The Public Works Research Institute and Japan Anchor Association have started joint research in order to publish the “Manual of inspection, integrity investigation and repairing of anchors” described in this paper.

1. Basic concept of anchor repair and types

Normal anchors having no need of repair work retain sufficient performance with respect to allowable limited level at both the initial stage of service and throughout the service life (Figure 1) even though the performance of the anchor deteriorates year by year. On the other hand, anchors that have deteriorated to below the level required for service at the time of investigation (as shown by A in Figure 2) or to the allowable limited level in some cases (as shown by B in Figure 2) require repair work. Some anchors provide an acceptable level of performance at the time of investigation but show signs that they will deteriorate further, and fall below the level required for service, before reaching the design service life (as shown by C in Figure 2). For these anchors, considered to be abnormal, repair work should also be provided.

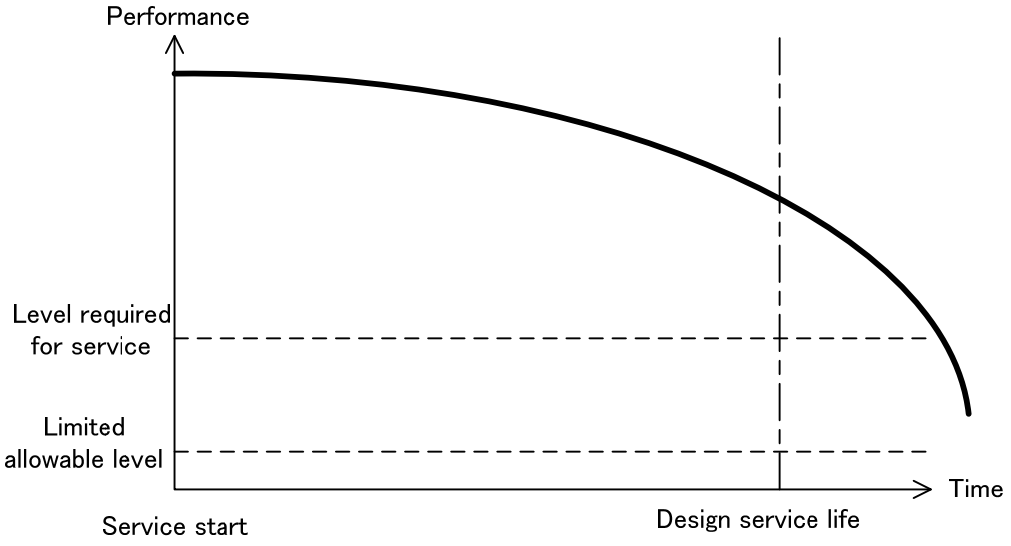


Figure 1. Illustration of normal anchor performance

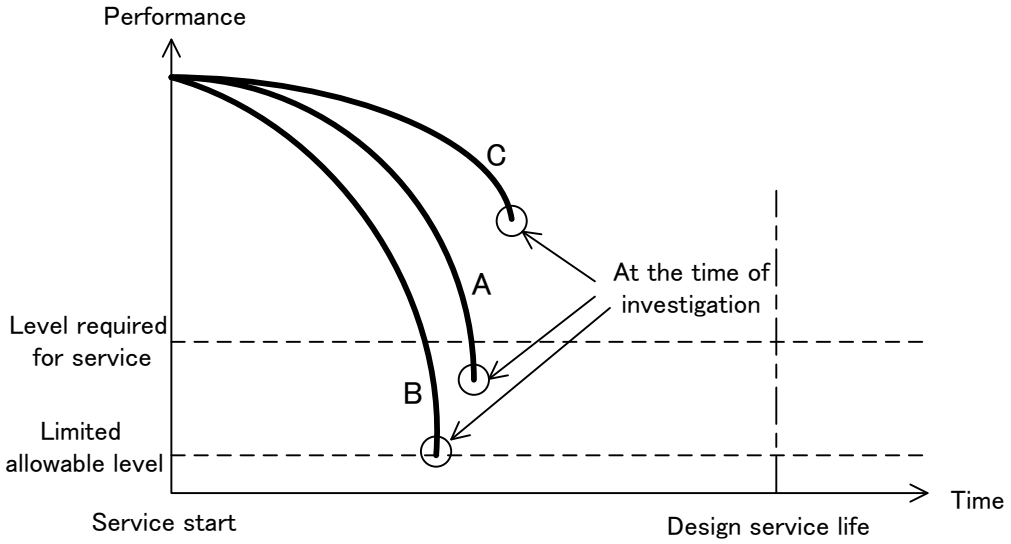
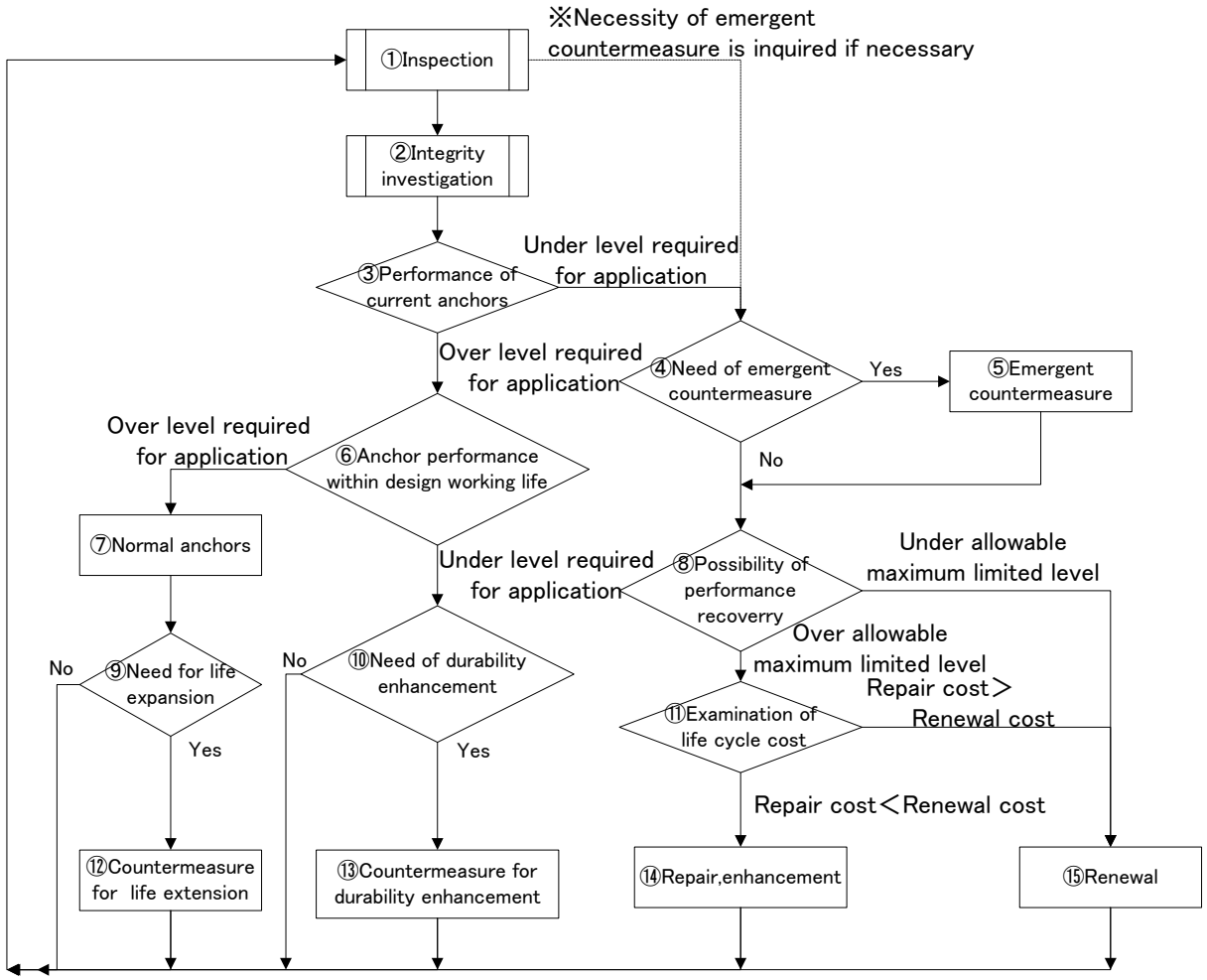


Figure 2. Illustration of anchors that cannot be considered normal

There are several types of repair that can be applied such as

(i) durability enhancement,
(ii) repair enhancement,
(iii) renewal,
(iv) emergency countermeasure and
(v) life extension countermeasure.

The basic flow chart for repair type selection is shown in Figure 3. Types and outline of repair works are also stipulated below.



①Inspection ②Integrity investegation ③Performance of current anchors
④Need of emergent countermeasure ⑤Emergent countermeasure
⑥Anchor performance within design working life ⑦Normal anchors
⑧Possibility of performance recovery ⑨Need for life expansion
⑩Need of durability enhancement ⑪Examination of life cycle cost
⑫Countermeasure for life extension ⑬Countermeasure for durability enhancement
⑭Repair,enhancement ⑮Renewal

Figure 3. Flow chart for selection of repair work

1.1 Durability enhancement

Based on the condition of the anchor at the time of investigation, Figure 4 indicates that the anchor is still above the level required for service, but the performance deteriorates drastically after the service start and is expected to fall below the required level for service within the design service life. In such case, a countermeasure, or durability enhancement, to maintain the performance of the anchor is necessary so that the required level of service is maintained for the design service life. The durability enhancement can extend the life of the anchor without improving performance, shown as (1) in Figure 4, or with improving performance, shown as (2) in Figure 4.

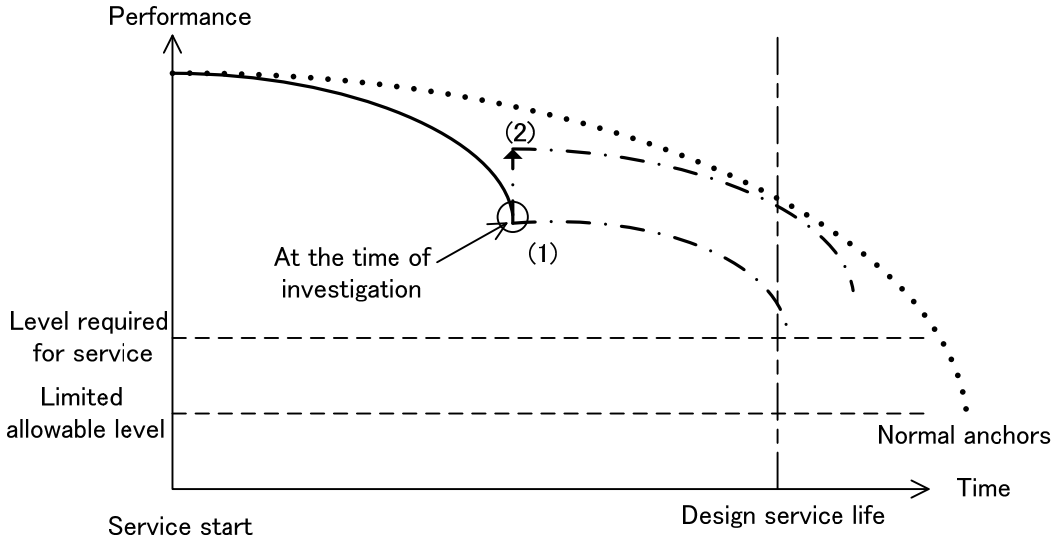


Figure 4 Illustration of durability enhancement

1.2 Repair enhancement

For anchors shown in Figure 5, performance deteriorates drastically after service start and is below the required level for service at the time of investigation. In such a case, performance improvement to the required level for service is implemented.

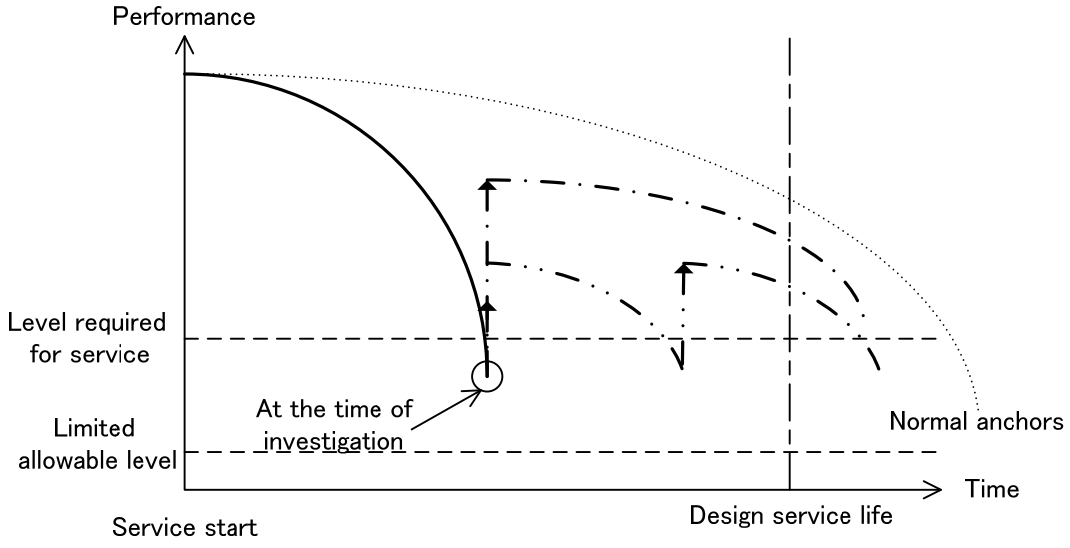


Figure 5 Illustration of repair enhancement

1.3 Renewal

New anchors are required in the case where the installed anchors are below the level required for service at the time of investigation and it is difficult to recover performance by repair enhancement due to technical constraints or would be disadvantageous in terms of cost or construction time, (Figure 6).

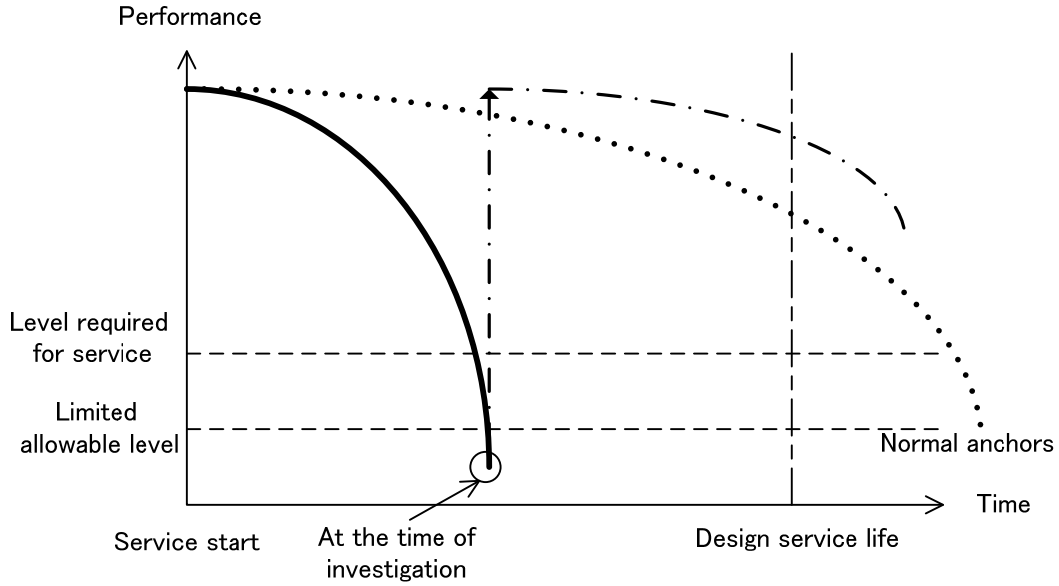


Figure 6 Illustration of renewal

1.4 Emergency countermeasure

Where anchors, anchored structures or slopes reach the allowable maximum limited level at the time of investigation, an emergency countermeasure should be taken in order to prevent third party damage before full-scale countermeasures are taken, (Figure 7).

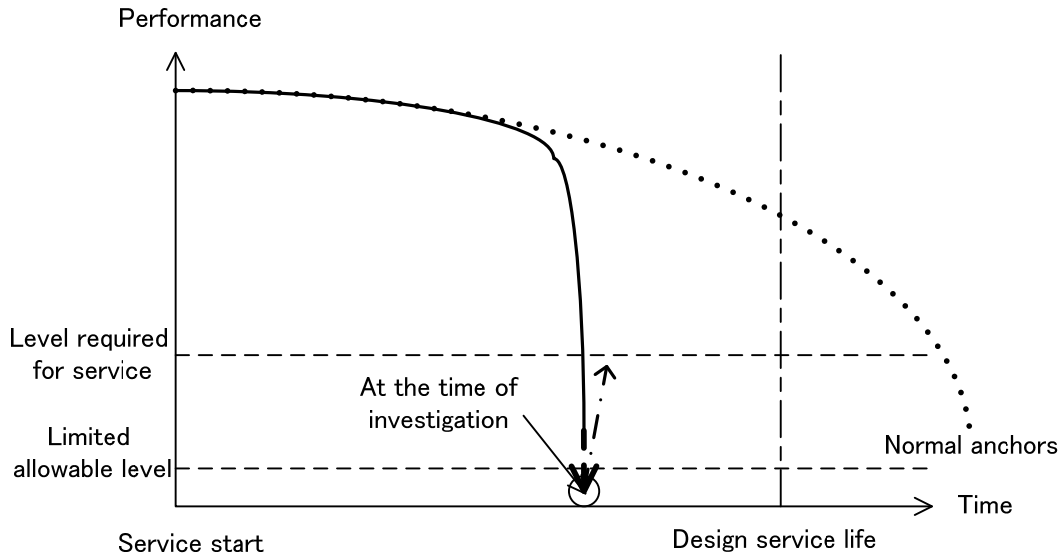


Figure 7 Illustration of emergency countermeasure

1.5 Life extension countermeasure

Normal anchors are expected to remain above the level required for service during their design service life. For such anchors, as they approach their design service life it is possible to keep them in service and thereby extend their renewal time by undertaking life extension countermeasures (Figure 8).

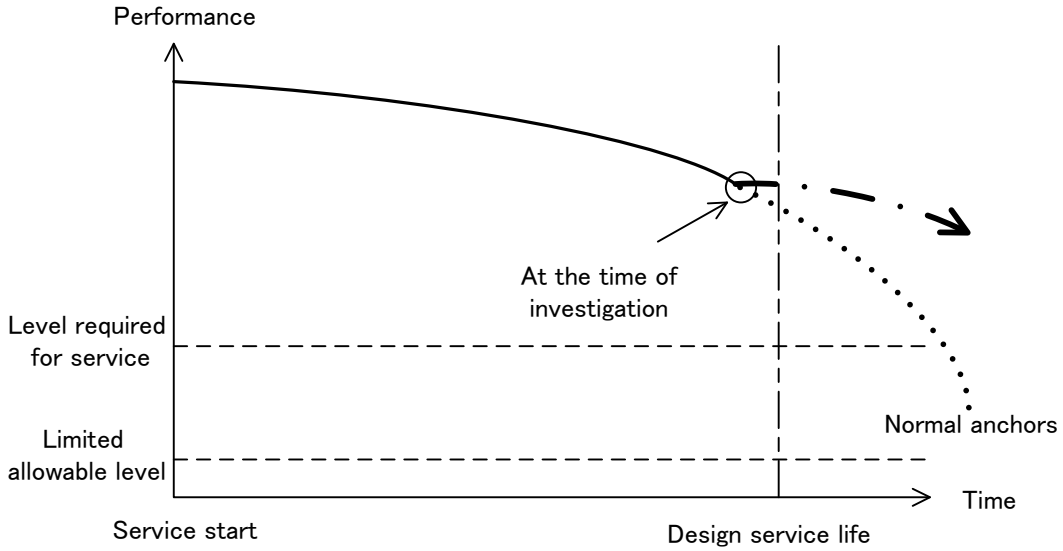


Figure 8. Illustration of life extension

2. Cause of and countermeasure for corrosion of anchor head and undershead

The causes of corrosion of the anchor head and underhead (below the bearing plate) are: -
(1) Insufficient corrosion inhibiting measures
(2) Deficient construction
(3) Deterioration of the corrosion inhibiting compound

The structure of the old type of anchor is shown in Figure 9. In old type anchors a discontinuous part existed below the bearing plate i.e. between the anchor head and the free anchor length sheath. Over this part the tendon easily corrodes when surrounded by air and water. For some anchor head parts, anti-corrosion treatment was not considered at all at time of construction, some of them were untreated by any corrosion inhibiting compound and some of them were provided with only a simple cap. Often where anti-corrosion treatment was considered such treatment was insufficient. Some of them were simply covered with concrete or a corrosion-inhibiting compound that leaked easily when the cover became loose. Such insufficient corrosion-inhibiting treatment is considered as the most common cause of corrosion for both the anchor head and the underhead part (below the bearing plate).

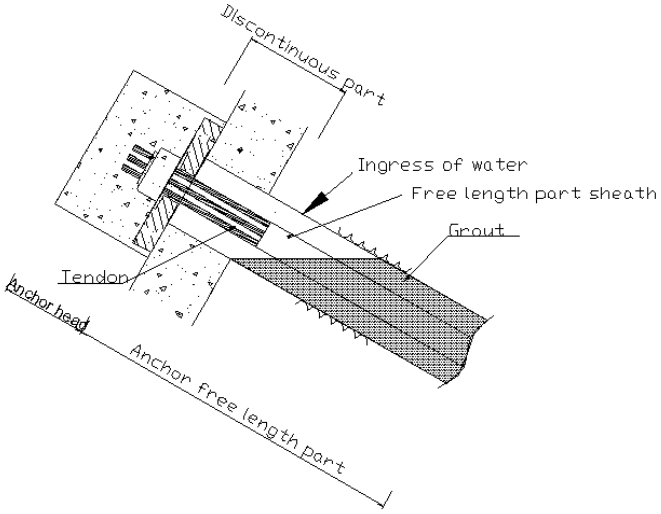


Figure 9. Constitution of old type anchor

The inside of the anchor free length part should be filled completely with corrosion inhibiting compound at the time of construction. However, during integrity investigation, it is often found that corrosion inhabiting compound for the free anchor length part is either insufficiently filled with, or completely empty of, corrosion inhibiting compound due to deficient construction or through damage to the free anchor length sheath. When the corrosion inhabiting compound does not completely fill the space between the grout that surrounds free anchor length and underside of the bearing plate, the ingress of water and air will cause corrosion to occur. Since the underhead part (below the bearing plate part) of the old type anchor includes a discontinuous structure, insufficient filling of corrosion inhibiting compound will increase the possibility of corrosion.

Corrosion inhibiting compound does not easily deteriorate in the absence of water and air. However, corrosion inhibiting compound in the anchor head cover will be deteriorated by air when it is insufficiently filled. Even if filling is complete at the construction stage, it will deteriorate when some of it leaks out and is replaced by water and air as a result of deterioration of the anchor cover seal or the head cover it is damaged.

Maintenance and enhancement of corrosion protection function is treatment for deteriorated anchors to prevent further deterioration of function, and treatment such as replacement of material. Maintenance and enhancement of corrosion protection function consist of two countermeasures such as protection of head part and countermeasures for corrosion protection oil and countermeasures against tendon, locking unit, bearing plate, and below anchor head. Selection example of countermeasures for protection of head and corrosion protection oil is shown in Figure 10 – 11.

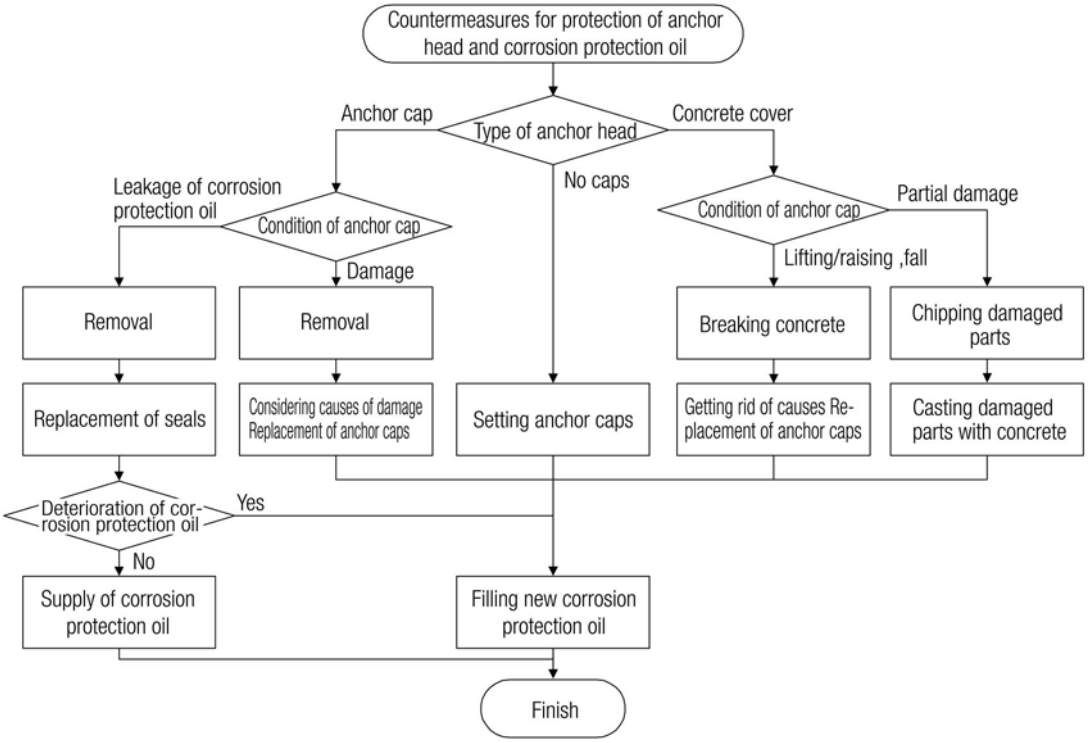


Figure 10 Examples of selection of countermeasures for protection of anchor head and corrosion protection oil

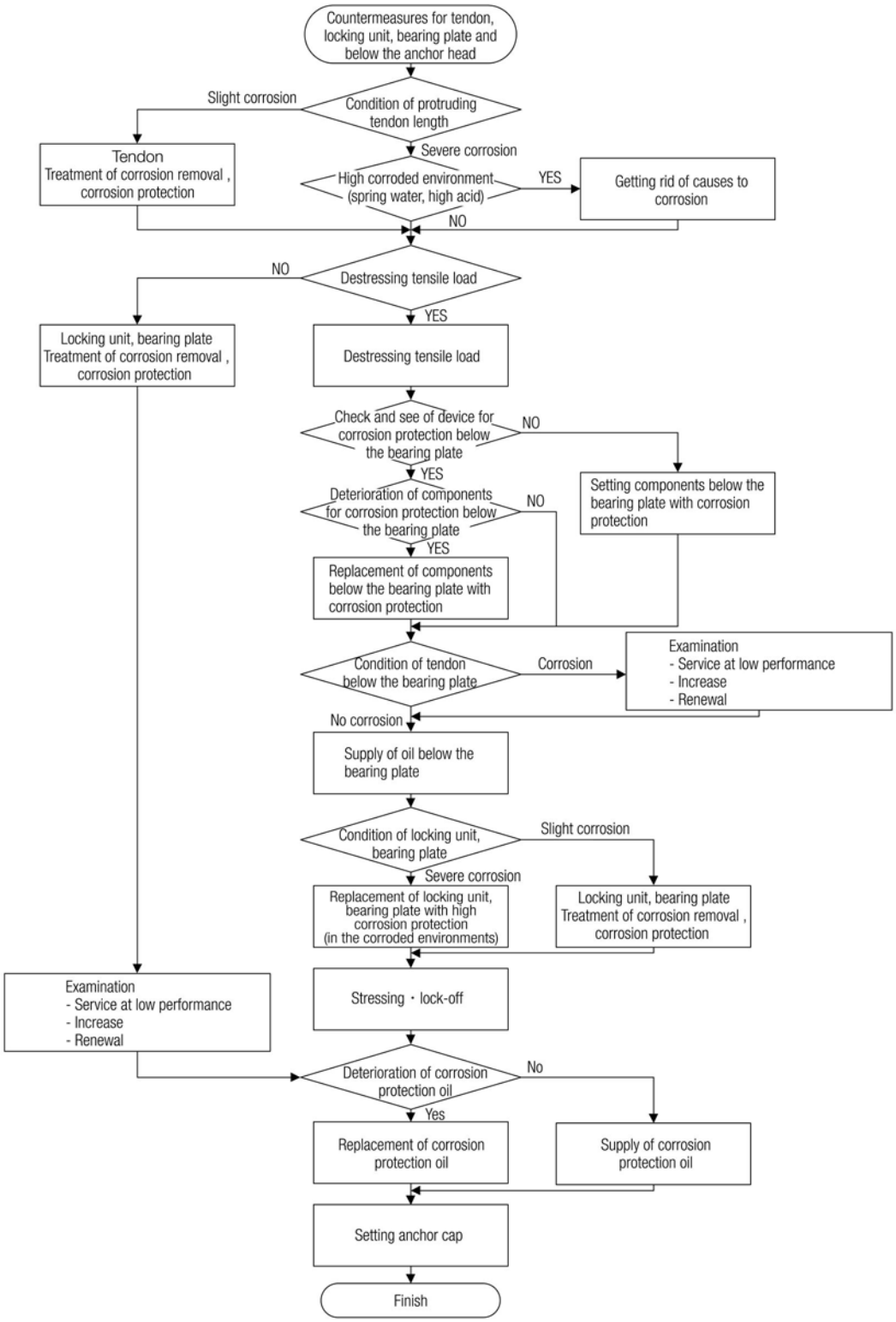


Figure 11 Examples of selection of countermeasures for tendon, locking unit, bearing plate and below the bearing plate

An example of a typical repair and enhancement of the anchor head and underhead part (below the bearing plate) of old type anchors considering the causes of corrosion is shown in Figure 12.

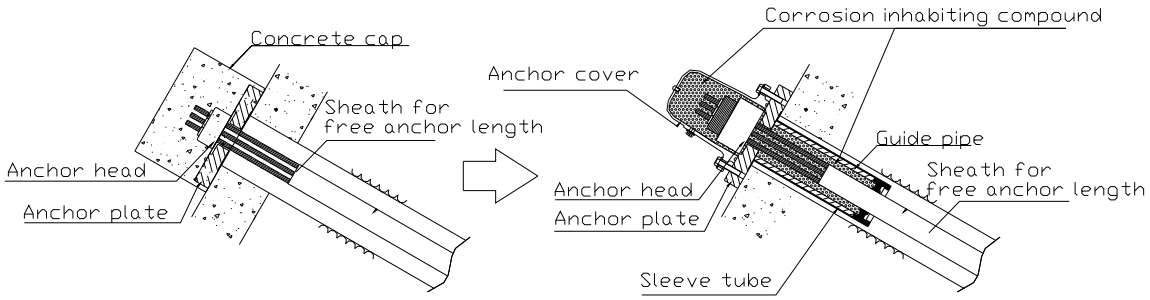


Figure 12. Repair and enhancement for the anchor head and underhead part(Below the bearing plate)

For the discontinuous part of the underhead part (below the bearing plate), joining is achieved by installing a sleeve pipe and guide pipe. Inside the sleeve pipe, the water stoppage rubber seal is set in advance. The new water stoppage rubber seal is operated through the anchor plate and guide pipe at the time tensile load is added to the anchor then worked as a watertight seal (Figure 13).

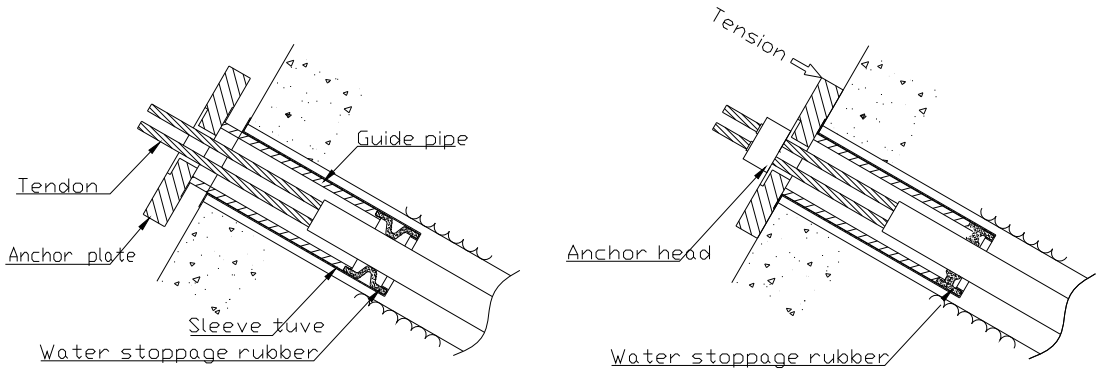


Figure 13. Example of water stoppage rubber

Then, the anchor cover is attached and pressurized corrosion inhibiting compound is grouted via a grease nipple. By pressurized filling, corrosion inhibiting compound fills the inside of the anchor cover, inside of the guide pipe (under head part-below the bearing plate) and inside the free length sheath (free anchor length). During the installation (using visual observation equipment) the corrosion-inhibiting compound was seen to push out and replace water and air as it filled. As for the management procedure, the filling pressure and amount of corrosion inhibiting compound are measured and recorded. Filling pressure should be confirmed to be over 0.4 MPa at the time of measurement (Figure 14.).

Figure 14. Pressure measurement

3. Conclusion

What is important, is to select the appropriate type of repair depending on the state or performance of the anchor at the time of investigation. For the selection of repair works to be implemented, one-time cost comparison is not enough, but life-cycle cost analysis should be taken into consideration.
Future issues to be considered are the development of more simplified methods of repair and new repair methods in the deeper part of the anchor.

References

Independent Administrative Institution Public Works Research Institute, Japan Anchor Association (2008) “Maintenance Manual fir Ground anchors”